THE WHITE ANGEL: AN ENIGMATIC WOLLASTONITE-BEARING F INCLUSION FROM THE LEOVILLE CV3 CHONDRITE

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The "White Angel", a ~4 mm long refractory inclusion from the Leoville CV3 chondrite, resembles a compact Type A inclusion in that it has an igneous texture and consists mostly of melilite but is distinct in that it contains large wollastonite crystals in its core in addition to minor fassaite and small amounts of perovskite. Spinel is almost exclusively restricted to the rim. Its petrography and mineral chemistry have been described previously [1]. Here we report O, Mg, Si, Ca and Ti isotopic compositions as well as trace element abundances measured by ion microprobe mass spectrometry.

The core of the inclusion exhibits mass fractionated Mg with a strong gradient from isotopically heavy Mg in the interior to normal Mg in the rim and the surrounding matrix (Fig. 1). Shown are the results of two traverses from the rim into the melilite core and measurements on isolated minerals in the rim and core. The degree of Mg isotopic fractionation ranges up to 20‰/amu, by far exceeding the range observed in "normal"CAIs [2] and putting this CAI into the company of FUN and F inclusions [3]. Although the Al/Mg ratios of melilite measured for ^{26}Al are limited, melilite shows clear evidence for ^{26}Mg excesses; the data are consistent with an inferred ^{26}Al/^{27}Al ratio of 5.3×10^{-5} (Fig. 2). Ion probe measurements of Si isotopic fractionation are more difficult than those of Mg. We found the core of the CAI to be enriched in the heavy Si isotopes by 3-5‰/amu relative to the matrix but could not find any clear evidence for a gradient such as observed for Mg. We made no attempts to measure the isotopic mass fractionation of Ca and Ti, but found no non-linear effects for Ca isotopes in melilite and Ti isotopes in perovskite within analytical errors of 2‰.

Preliminary results of *in situ* O-isotopic measurements indicate fractionated oxygen, although the precise degree of fractionation is still not well known. In addition, different mineral phases exhibit variable amounts of ^{16}O-enrichments. The largest enrichments of ~47‰ are observed in two large, well-crystallized wollastonite grains. In contrast, the ^{16}O-enrichments in two spots of wollastonite in a partially melted portion of the CAI are only 16 and 20‰, respectively. Enrichments in a fassaite crystal are 26 and 30‰, while they are only 7 and 8‰ in two perovskite grains. The smallest ^{16}O-excesses of 4 and 8‰ are found in melilite.

The REE patterns measured in different minerals are shown in Fig. 3. The two perovskite patterns span the range observed in 10 individual grains. With their depletion in the HREE (except for Tm and Yb) they resemble patterns seen in a few single Murchison perovskite crystals [4] and hibonite- and grossite-rich inclusions [5, 6]. The other phases are depleted in **all** REE except the most volatile REEs Eu, Tm and Yb. Such a pattern, the complement of the extremes of Group III pattern [7], as they are found in hibonite grains [4], has previously been seen only in the rim of a grossite-rich inclusion [6], but never in the core of a melilite-rich CAI.

The observations made on the White Angel inclusion raise several puzzles. The lack of any isotopic anomalies in ^{48}Ca and ^{50}Ti in melilite and perovskite as well as the evidence for ^{26}Al at the level of $5\times10^{-5}\times{}^{27}$Al indicate that the White Angel is not a FUN [8] but at best an F inclusion such as Allende CG-14 and TE [9]. The overall REE pattern suggests condensation from a reservoir depleted in the refractory REEs. However, such a pattern seems to be incompatible with isotopic fractionation of the Mg and O by evaporative loss of material from the inclusion. An F_{Mg} value of 15‰/amu implies a Mg loss of 60% [10] and for this degree of Rayleigh distillation, at least from an initial chondritic composition, a substantial Ce depletion is expected [11]. The oxygen isotopic data are also not easily understood. The difference in ^{16}O-enrichments between different wollastonite crystals can be explained by partial isotopic equilibration in the partially melted areas of the inclusion. However, the small degree of ^{16}O-enrichments in fassaite and especially in perovskite relative to that in the well-crystallized wollastonite are not expected. However, additional measurements are needed to determine whether this holds also for other perovskite grains.

REFERENCES: [1] Caillet C. and Buseck P. (1992) *Meteoritics* 27, 208. [2] Clayton R. N. *et al.* (1985) In *Protostars and Planets II*, (D. C. Black and M. S. Matthews) 755-771. University of Arizona Press, Tucson. [3] MacPherson G. J. *et al.* (1995) *Meteoritics* 30, 365-386. [4] Ireland T. R. *et al.* (1988) *Geochim. Cosmochim. Acta* 52, 2841-2854. [5] Kimura M. *et al.* (1993) *Geochim. Cosmochim. Acta* 57, 2329-2359. [6] Weber D. *et al.* (1995) *Geochim. Cosmochim. Acta* 59, 803-823. [7] Martin P. M. and Mason B. (1974) *Nature* 249, 333-334. [8] Lee T. (1988) In *Meteorites and the Early Solar System*, (J. F. Kerridge and M. S. Matthews) 1063-1089. University of Arizona Press, Tucson. [9] Clayton R. N. *et al.* (1984) *Geochim. Cosmochim. Acta* 48, 535-548. [10] Davis A. M. *et al.* (1990) *Nature* 347, 655-658. [11] Floss C. *et al.* (1996) *Geochim. Cosmochim. Acta* 60, 1975-1997.

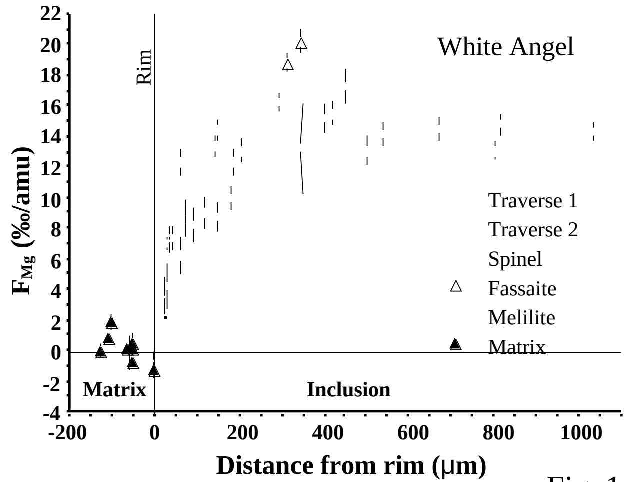

Fig. 1

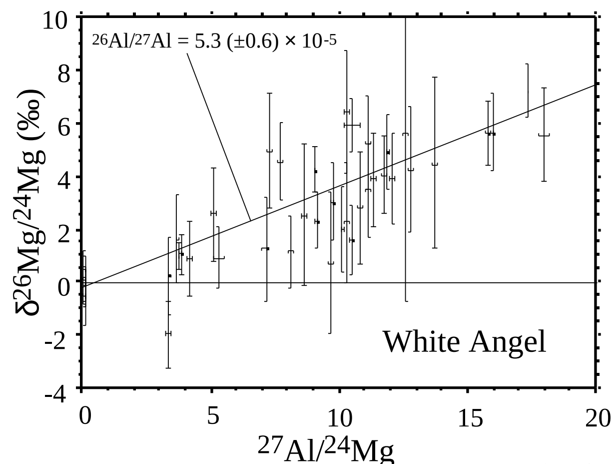

Fig. 2

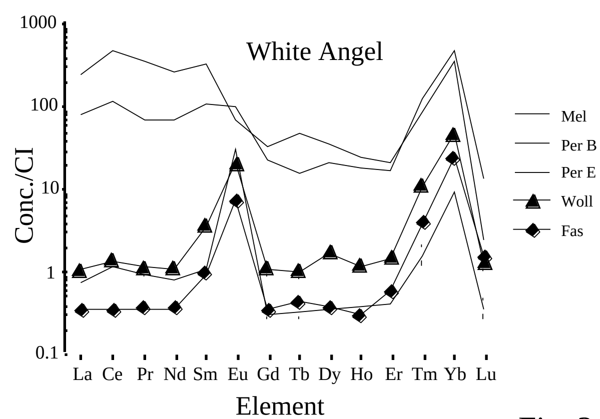

Fig. 3